Mineral Development in Ontario North of 50°

Technical Paper #10

Platinum

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and
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the ROYAL COMMISSION on the NORTHERN ENVIRONMENT

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1981

This technical report provides background material for the final report Mineral Development in Ontario North of 50°, submitted to the Royal Commission on the Northern Environment by Laurentian University in September, 1982.

However, no opinions, positions or recommendations expressed herein should be attributed to the Commission; they are solely those of the authors.

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INTRODUCTION

The purpose of this chapter is to bring out the instrumental role which the noble platinum-group-metals - the PGMs - play, not only as precious metals in jewelry, but also as vitally important agents in our modern technological society. Furthermore, it is to show that the amounts of these metals used are small compared to other metals in face of an obvious abundance of ore reserves concentrated in a few countries. Combined with a complex metallurgy, a small number of refineries, at source and at the market, contribute to a highly interrelated market structure dominated in one way by two countries - South Africa and the Soviet Union - as duopolist countries, and on the other by an oligopolistic arrangement of a few firms at both ends of the supply side which are highly interconnected. The resulting stability of prices - as posted by the major producers - speaks for an orderly operation in the market with the fear of future instability and disruption not deriving from the horrendous stockpiles of the U.S.S.R., but from a small amount of recently and privately acquired PGM inventories which could be released into the market.

Under these conditions, a competitive forecast would envisage larger quantities consumed at lower prices than one

could normally expect, under these market conditions of highly imperfect competition. Nonetheless, the required technological change that is sweeping the world, including the underdeveloped countries, will push the consumption of PGMs up by more than the other authorities in the forecasting field predict. However, the question which has not been touched upon but which follows logically from this entire, though in some way preliminary, analysis concerns the actual benefit Canadians derive by proudly pounding their chests to be citizens of the third largest PGM-producing country of the world, metals of which 20 percent are lost as waste in refineries on foreign soil.

The analysis is organized in the following way: Section I discusses briefly the metals as to their general properties, qualities, occurrences and uses which bestow the adjective of 'noble' upon them. The analysis of consumption of the PGMs follows in much greater detail in Section II as various industrial applications of the PGMs are explored. World, Canadian and Ontario production are studied in Section III, which also tries to shed some light on the performance of the main producing countries in the world for the years 1950 to 1979. Likewise, this section briefly reviews the Canadian trade in PGMs between 1977 and 1979 and it carefully scrutinizes the problem of PGM refineries in the world. A serious view is taken of the world PGM reserves and of the alternative suppliers of these metals

in Section IV. In addition, other types of supplies of the metals and other suppliers are focussed upon in the same section which also takes a serious look at stocks and inventories as may be hanging over the market. The results of the econometric analysis of the future of platinum prices and PGM production are presented in Section V, which also examines very critically the obvious presence of severe market imperfection with summary and conclusions to follow.

SECTION I: THE METAL

The nobility among metals consists of the following minerals:

PLATINUM IRIDIUM OSMIUM PALLADIUM RHODIUM

RUTHENIUM GOLD SILVER

These eight metals make up the precious metals. Two of them, gold and silver, have for long served in a monetary capacity in which they are joined by platinum which people use to a larger degree than ever before as a store of value - as a hedge against inflation. It is towards this nobly precious metal - platinum - that our interest now turns.

Platinum is a very heavy mineral and it has a colour which resembles a mixture between steel gray, grayish-white and silver-white.[1] The mineralization in which it occurs generally contains other elements such as the likewise noble metals palladium and iridium, and with iron, nickel, copper and chromium. Platinum occurs in alluvial deposits, igneous intrusions and in mafic and ultramafic rocks.[2]

In Ontario, it is associated with nickel sulfides in the Sudbury Basin, but it may also be mined jointly with gold

ores. Electrolytic refining of copper leads likewise to recovery of platinum. Platinum is also being found in coal and lignites, especially in the ashes.

The properties of this precious metal are its corrosion resistance, its resistance in conductivity and its softness. To this must be added a catalytic quality, chemical inertness as regards wide temperature ranges and the high melting points. This holds, essentially, for all PGMs. It compares well with the other two ancient precious metals, gold and silver. Compared to the other five metals of the platinum group,[3] platinum has the definite advantage that it is the most abundant of them all.

These properties explain to some degree the various uses to which it may be put. As a precious metal, it is wrought into jewelry and one can argue that the public has started to buy platinum jewelry to protect itself against inflation. Modern computer technology has expressed strong interest in platinum and the group of its metals as the electrical field absorbs a substantial amount of them. This metal, and the others in the group, are also needed as catalysts in the chemical and petroleum industries; they serve the purpose of pollution abatement. In medicine, they are useful in the fields of surgery, cardiac therapy and, in diluted form, as painkillers and agents in the treatment of cancer; in dentistry, platinum group metals

are of considerable importance; they are an absolute necessity in the glass industry for the processing of fibres or for handling molten glass; other applications of these metals are in the metallization of glass, in ceramics and in crucibles and refractories. It is one of those metals which is used in very small quantities but in its applications determines and improves not only the qualities and varieties of manufactured goods but contributes largely to the general improvement of life and health of mankind. Therefore, the platinum metals are very 'noble' metals, indeed !

SECTION II: CONSUMPTION

General Consumption Pattern: U.S.A.

The consumption of platinum group metals in the United States increased dramatically over the period 1964 to 1978. From a consumption figure of 1,050,000 ounces in 1965, it rose to 2,119,913 ounces in 1978. This is set out in Table 1.

Table 1

Platinum Group Metal Consumption in the U.S.A. for the Years 1964 to 1978 in '000 troy ounces & in metric tons

Years	'000 troy ounces	metric tons	Years	'000 troy ounces	metric tons
1964	1,050	32.66	1972	1,562	48.58
1965	1,188	36.95	1973	1,803.1	56.08
1966	1,709	53.19	1974	1,981	61.62
1967	1,211	37.67	1975	1,310	40.75
1968	1,296	40.31	1976	1,603	49.86
1969	1,360	42.30	1977	1,592	49.52
1970	1,331	41.40	1978	2,112	65.69
1971	1,262	39.25			

Source: See Table A2

A more careful observation may give a less biassed incline. There is a rising trend in the consumption of platinum metals in the United States. When the combined averages of the first and

last five years are used in such a comparison, it is clear that there is a rising trend showing a 33.2 percent incline over the 10 year averaging period. Roughly speaking, the consumption of the PGMs has been rising at 3.32 percentage points annually as 40.148 metric tons were consumed during the first 5 year averaging period and 53.488 metric tons in the second. It is also clear that this consumption had its ups and downs notably through general economic fluctuations in manufacturing and investment goods industries.

Industrial Use Pattern

The United States is one of the few countries for which detailed breakdowns are available for each of the PGMs by industrial use sectors. A summary picture for all PGMs is presented here with further information contained in Tables A1 and A2 in the Appendix to this chapter.

Automotive Industry

Table 2 tells part of the story. From 1973 to 1974, an 8.19 percent increase in the usage of all platinum metals was noticed. This was the first year that platinum and palladium were used to a large degree in the automotive industry to reduce emission of pollutants.[5] This means that the increase in the consumption of PGMs in recent years is mainly a result of the

Table 2

Distribution of PGM Use in the U.S.A. by Type of Consuming Industry

for the Years 1964 to 1978

Year	Automotive Industry	Chemical Industry	Petroleum Industry	Glass and Ceramics	Electrical Industry	Dental and Medical	Jewelry and Arts	Miscellaneous Industrial Uses
1964	---	26.10	8.29	7.05	44.37	6.66	6.10	1.43
1965	---	25.93	10.10	2.69	46.38	6.48	5.47	2.95
1966	---	25.45	15.57	7.37	38.68	5.50	4.97	2.46
1967	---	31.38	10.49	4.71	36.33	6.77	5.37	4.95
1968	---	31.33	8.72	4.24	35.58	6.79	5.55	7.79
1969	---	31.18	4.93	5.74	41.03	5.58	5.00	6.54
1970	---	28.55	12.02	5.63	41.02	5.11	4.28	3.38
1971	---	30.82	11.17	3.57	39.55	6.81	3.88	4.20
1972	---	37.70	8.32	2.75	34.33	8.07	3.20	5.63
1973	---	31.29	7.86	4.97	37.38	8.96	3.33	7.21
1974	25.24	21.55	8.38	4.64	27.82	7.62	2.93	1.81
1975	28.20	24.10	8.80	4.30	17.30	10.20	4.00	3.10
1976	42.14	14.87	4.18	3.05	17.89	10.44	2.38	5.05
1977	30.17	17.64	5.55	4.72	21.65	8.86	3.56	7.85
1978	37.60	15.40	5.90	5.40	19.10	8.80	2.20	5.60

Source: See Table A1

huge demand exercised by the automobile industry which absorbed 32.67 percent as the average over the last 5 years (Table 2). Any upturn in the North American automotive industry would have a significant impact on the consumption - and thus on the demand - for the PGMs, particularly for platinum and palladium.

Chemical Industry

Given the properties of platinum and of the other metals in the group, they are among the most efficient catalytic agents in the chemical industries. These industries were the first to use PGMs and, over time, ever and ever new uses were discovered. In the United States, the use of the PGMs in chemical industries has fallen seriously in the 1970s. Between 1974, 1975 and 1979, the relative strength of these metals used chemically declined from 24.1 percent to 15.4 percent. In one year, its share dipped even below the 15 percent mark. It means that platinum metals are not any longer as important as they once were for this particular industrial sector. It is interesting to note that there is another important use of platinum. This has to do with the oxidization of ammonia to produce nitric acid. This process had been long discovered, viz. in 1839. Yet, it was only used in the production of fertilizers and explosives at the beginning of the 20th century. It is therefore apparent that in times of military conflicts of larger proportions, the consumption of PGMs by the chemical industries is rising with

subsequent declines after the sad events have become history. Inroads by foreign competition in the chemical fields may also explain the relative decline of usage of PGMs in this particular sector.

Glass and Ceramics

The discovery of the usefulness of platinum in the glass industry goes back to Michael Faraday who laid the foundation for using platinum in connection with molten glass, especially optical glass. Today, platinum bushings[6] are the sine qua non of the fibre glass industry. In the United States, the use of PGMs in glass and ceramics, including resistor pastes and printed circuit pastes, in glass metalization and refractories went up to 5.4 percent in the 1970s. There are indications that the need in this area will continue to make important demands on the PGMs.

Petroleum Industry

The petroleum industry uses platinum and palladium for catalytic cracking and reforming of petroleum. These metals are also found in connection with the hydrogenation of coal. In the United States, the amount of PGMs consumed was over 15 percent of the total in the year 1966. However, the petroleum reforming process has undergone a technological change. Formerly, a mono-metallic platinum catalyst was used as a

converter. In the course of time, the industry switched to a less expensive bi-metallic platinum-rhenium catalyst with a longer life expectancy. The situation which evolved was so severe that the major petroleum companies, at one time, started to sell platinum from their inventories. This explains why the use of platinum in the petroleum industry has undergone such a strong decline.

Electrical Industry

The electrical industry is another sector in which the use of platinum has been replaced by cheaper substitutes. Normally, it is used in electrical furnaces and thermocouples, for electrical contacts in telephone equipment and, in connection with other PGMs, in printed circuits.

The decline may be seen again in Table 2. At one time, long before the automotive industry entered the field, over 46 percent of platinum metals went into the electrical industry. By 1978, however, their significance has been reduced to 19.10 percent. It is obvious that in the electrical field, platinum is more exposed to substitutes. It is in this area that platinum is 'dissipative' and cannot be easily recycled.[8] This is in contrast to the other uses where platinum is non-dissipative: it can be recovered - like in automobile engines. Therefore, the decline in importance of platinum is quite understandable, although this does not mean that substitution will end here.[9]

Dental and Medical Field

On account of the distribution set out in Table 2, the consumption of platinum metals is relatively strong and still on the increase. Whereas in earlier years the consumption of these metals fluctuated around 5 and 6 percent, in the later 1970s, these values were around the 9 percent level.

In the dental field, platinum and palladium are used in various forms. They are applied in unalloyed form; they are also found mutually alloyed; finally, platinum is alloyed with iridium, while palladium is alloyed with gold, silver and copper.[10]

In the medical field, platinum is a painkiller and chemotherapeutic agent in the treatment of cancer patients; the deployment of ultra-fine platinum compounds have opened a new field of cancer research and therapy. It is called "cis-platinum II"! - Or, consider the pacemaker. It has platinum-iridium electrodes which are implanted into the heart, and, in turn, are stimulated by electric currents.

Platinum, when alloyed with iridium, produces a substance of unsurpassed sharpness most suitable for surgical instruments.[11] Unusual magnetic strength results from alloys of platinum and cobalt which prove very useful for artificial eyes and teeth.

Jewelry and Arts

The amount of platinum wrought artistically into jewelry is as substantial as it is an old and venerable custom. It has a long history. Mohide elaborates on the importance of platinum at the Russian Imperial Court, especially in connection with Peter Carl Fabergé, Russia's famous court jeweller.[12] Among the famous pieces of art created by this man, there were sophisticated mechanical easter eggs which were made of platinum. They are museum pieces today of priceless value.

One great advantage of platinum is that it provides a firmer setting for precious stones than gold. Today, the United States' jewelry industry consumes but a small percentage of platinum and related metals. In 1964, over 6 percent of all platinum was absorbed by jewelry. By 1978, it had gone down to 2 percent.[13] This performance of the jewelry industry is symptomatic for the world as a whole, with one exception and this exception is Japan. This country has succeeded in becoming the world's most outstanding consumer and producer of platinum jewelry. It developed what Greig called a "voracious appetite for platinum for jewelry."[14] During the 1970s, the Japanese emerged with a jewelry industry which absorbs now 75 percent of the PGMs needed by that country.[15] For 1974, Mohide reported that the U.S.A. used not quite one ton of platinum for jewelry. This stands in glaring contrast to Japan's 24.7 metric tons absorption for the same purpose.[16]

Miscellaneous Uses

Among the other uses of platinum metals which, in the United States, account for up to almost 8 percent of total PGMs absorbed, there is one with extraordinary potential. This special use area is to be found in the application of platinum catalysts in fuel cells, the chemical generations of electricity.[17] Using hydrogenated naptha, this fuel cell may deliver electricity on a standby basis for hospitals, to give one example, or it may be in the form of a power plant, generating 4.5 megawatts. One of these units will be coming onstream shortly in the United States and another in Japan.[18] Another example of application is what Greig calls the "less pleasant example" of the development of a new German submarine type which would be running on such a source of power supply.-

Ever since the Environmental Protection Agency started its battle against pollution and for human welfare, an ever-increasing quantity of PGMs have been absorbed through new technological innovation to accomplish environmental aims. This means that technological change has a very strong and positive effect on the use, function and importance of the PGMs. In this sense, the development of the consumption patterns does portray rising demand pressure for the supply of PGMs as new technological marvels unfold. This, in turn, will be coupled with newer and better ways of producing larger quantities of commodities as world GDP rises, even if the search for workable or better substitutes for PGMs may produce the occasional success.

SECTION III: PGM PRODUCTION

World, Canada and Ontario

The world has experienced a very strong rise in the mining output of platinum metals over the study period. From 419,600 troy ounces (13.05 metric tons) in 1950, output rose to 6,659,500 troy ounces (207.13 metric tons) in the year 1979. This is an almost sixteen-fold increase, a very steep climb indeed. It has been set out in Table 3.

Over the same period, Canada displayed a slower rate of expansion in the production of PGMs. From 124,000 troy ounces, it enlarged its output to 465,000 in the year 1977; this is a rise by a factor of 3.7. The reduced output levels for the years 1978 and 1979, as presented in the same table, reflect the impact which cutbacks and the strike in Sudbury had on the mining output of the noble metals.

Since most of the platinum metals produced in the world are by-products from the mining of nickel-copper sulfide ores, the Canadian output trend mirrors quite descriptively the development of nickel mining in Canada.

For the simple reason that the Canadian nickel mining industry is concentrated in the Sudbury Basin of the Province

Table 3

World Production of Platinum and the Distribution for

Canada and Ontario for the Years 1950-1979

in '000 of troy ounces

	Area		Percentage Share	
Year	World	Canada[2]	Canada	Ontario[1]
1950	419.6	124.6	29.7	29.7
1951	492.8	153.5	31.1	31.1
1952	474.3	122.3	25.8	25.8
1953	579.5	137.5	23.7	23.7
1954	852.9	154.4	18.1	18.1
1955	960.0	170.5	17.7	17.7
1956	1235.4	314.8	25.5	25.5
1957	1443.1	416.1	28.8	28.8
1958	1014.7	300.5	29.6	29.6
1959	1130.43	328.1	29.0	29.0
1960	1316.07	483.6	36.7	36.7
1961	1215.7	418.3	34.4	34.4
1962	1196.6	470.8	39.3	39.3
1963	2442.1	357.7	14.6	14.6
1964	3341.5	376.2	11.3	11.3
1965	3563.1	463.1	13.0	13.0
1966	3546.6	396.1	11.2	11.2
1967	3568.6	401.3	11.2	11.2
1968	3687.0	485.9	13.2	13.2
1969	3623.8	310.4	8.6	8.5
1970	4328.9	482.4	11.2	11.2
1971	4072.0	475.2	11.7	11.7
1972	4545.1	399.0	8.8	8.7
1973	5232.1	354.2	6.8	6.7
1974	5769.2	384.6	6.7	6.7
1975	5713.7	399.2	7.0	7.0
1976	5991.7	430.0	7.2	7.2
1977	6382.3	465.4	7.3	7.3
1978	6332.2	346.2	5.5	5.5
1979	6659.5	185.0	2.8	2.8

Source: American Metal Market, Metal Statistics; ABMS Non-ferrous Metal Data, 1979, New York, N.Y.; United Nations, Statistical Yearbook, New York, N.Y.; Statistics Canada,

...cont'd.

Table 3 cont'd.

[1]Although Ontario's share in Canadian output of platinum has been 100 percent for 17 of the years between 1950 and 1979, during the remainder platinum was produced in British Columbia 1950, 1951, 1959, 1962, 1963, in insignificant amounts; the same holds for Saskatchewan 1966-1967, and the Yukon 1972 and 1973. Ontario's share dipped to 99.1 percent in 1972.

[2]The Canadian value for platinum refers to all platinum metals except osmium, viz. platinum, palladium, rhodium, ruthenium and iridium. See Statistics Canada, Nickel-Copper Mines, 1977, cat. 26-211, p. 10.

of Ontario, a definite identity exists between the time series of PGMs produced in Canada and Ontario. Following the statistics of Statistics Canada, Ontario is the main producer of nickel and thus of platinum metals in Canada. The production of nickel in Manitoba by the Thompson operations of INCO and the resulting PGMs must have been included, therefore, under the Ontario output.

At one time, Canada had become a very important world mine producer of the PGMs. This had been accomplished through the mining activities of the two Ontario-based companies: Falconbridge Mines and INCO. Between the years 1950 and 1962, Canada's and Ontario's shares fluctuated between 29.7 and 39.3 percent of the world total. In 1954 and 1955, it took a short dip to 18.1 and 17.7 percent respectively, but it always recovered the lost ground; and then, suddenly, the world share collapsed to 14.6 and 11.6 percent for the years 1963 and 1964 respectively. The reasons for this very dramatic, though relative decline was the tremendous expansion of production of other countries. Between 1962 and 1963, the platinum metal output recorded for the U.S.S.R. rose from 375,000 troy ounces to 1,700,000 troy ounces, or from 11.6 to 52.88 metric tons respectively. In the following year, South Africa entered the scene with full force. It scored an unusual expansion in the output of platinum group metals which rose from 306,000 troy

ounces (9.5 metric tons) to 604,000 troy ounces (18.8 metric tons), almost doubling the annual output. Russia, at the same time, pushed its PGM production to 2,300,000 (71.5 metric tons) for the year. It is, therefore, the effect of the combined efforts of expansion by these two countries which forced Canada on the sidelines. At best, Canada - or Sudbury for that matter - produced 7.3 percent of the noble metals for the world at the end of the 1970s, which amounts to a substantial difference when compared to the 39.3 percent at the height of its world stature as a platinum mining producer!

The Main Producers of the World

The distribution of production of world platinum metals is shown in Table 4. In 1960, Canada and the U.S.S.R. were running a close struggle for first place. Canada was quite successful at that time. Eventually, however, the U.S.S.R. overtook this country as the Soviet share of world PGM output was 64.6 percent. This was not to last long, because South Africa, which had been in third place in 1950, emerged finally as the main producer of the metals, and that of platinum in particular. The fourth position had been held by the United States. From a significant production share of 9 percent, it went almost to zero! The fifth largest producer was the one which had been the first country to produce platinum: Colombia!

Table 4

Distribution of World Production by Countries in percentages

for Selected Years 1950 to 1979

	1950	1955	1960	1965	1970	1975	1979
Australia						0.0	0.2
Canada	29.7	17.7	36.7	13.0	11.2	7.0	2.8
Colombia	6.3	2.9	2.2	0.3	0.6	0.4	0.2
Japan						0.3	0.5
South Africa	25.2	37.9	30.8	21.2	34.7	45.5	48.1
U.S.S.R.	29.8	39.1	28.5	64.6	53.1	46.4	48.1
U.S.A.	9.0	2.4	1.8	0.9	0.4	0.3	0.1
	100.0	100.0	100.0	100.0	100.0	99.9	100.0

Source: American Metals Market. Metal Statistics, New York, N.Y.

ABMS. Non-ferrous Metal Data, 1979, New York, N.Y.

It was the first country to placer mine the metal, beginning in 1778. This country, which had been at the beginning, still produced 6.3 percent of the world total in the year 1950; in 1979 this share had shrunk to a mere 0.2 of 1 percent. At the beginning, Czarist Russia had been the second to join in the production of this metal through placer deposits in the Ural Mountains; the output of platinum as a by-product took place in Russia after 1940 when new sulfide nickel mines were opened up on the Kola Peninsula and in Norilsk. Canada only became a platinum mine producer in 1909 when the metal was recovered from operations in nickel-copper mining; and it was only in 1924 that South Africa entered this scene which it finally was to dominate.

However, during this period under study, several new and small PGM mine producers emerged. There is, at first, Australia. In the year 1975, it produced 1,830 troy ounces and 11,500 in 1979. For the same year, Yugoslavia is reported with an output of 5,700 troy ounces of PGMs. Japan also started to look for the precious and noble metals. In 1973, a first output is listed amounting to 10,197 ounces of platinum. The annual output of this country rose to 15,205 ounces in the following year and to 19,401 ounces in 1975. By 1979, it reached 34,200 ounces (32,453 for 1978) which is slightly more than a metric ton.

Since 1973, Ethiopia has had an output entry on the platinum metal list. Specifically, the values are:

Years	Ounces
1973	235
1974	230
1975	162
1976	200
1977	100
1978	123
1979	100

The metal was recovered from placer deposits and, as much as is known, this type of operation is continuing with technological assistance extended by the U.S.S.R.

Finally, there is Finland. It was the year 1973 when Finland's PGM output appeared in the statistics with the following quantities produced over the years.

Years	Ounces
1973	725
1974	650
1975	600
1976	640
1977	720
1978	640
1979	720

Obviously, these last three countries are insignificant producers of PGMs and it is interesting to note that these countries - generally called sundries - appear quietly on the scene. However, it would be an error to underestimate the latent potential of platinum mining of these and of all those countries which are, or may one day be, engaged in the mining of nickel and copper sulfides. Over time, they may quite well deliver

increasing amounts of PGM output to toll refineries. The sum total may one day be significant in world terms - setting the significance level between one, as the lowest, and five, as the highest respectively for "sundry producers".

Canada's Foreign Trade in PGMs

On the balance sheet, the Canadian trade in platinum metals is positive in terms of both quantities and values in $ Canadian. However, due to the special situation as existed in the Sudbury area in 1978 and 1979, the decline in Canadian PGMs is also present on the export side.

Six different metal types enter the platinum trade. The first, which is also the largest item, consists of the export of ores and concentrates.

In the year 1979, 4.91 metric tons were shipped to other countries, mainly to the United Kingdom. In 1978, they had been 10.56 metric tons and 12.39 metric tons in 1977. Of these, 96.6 percent went to the United Kingdom in 1979, while in the previous year every single ounce had been shipped to the United Kingdom, a point which will have to be discussed further below. The overall performance is contained in Table 5.

The second type deals with the exports of platinum scrap. The amount exported was between 0.994 metric tons in 1977 and 1.531 metric tons in 1979. Here, the number of customer countries is larger than in the first category and the lion's share of

Table 5

Canadian Exports of Platinum Metals in Ores and Concentrates

for the Years 1977 - 1979

(item 256-29)

Year	Ounces	Metric tons	Value of Shipment $ Can. '000
1979	157,719	4.91	47,497
1978	339,419	10.56	55,062
1977	398,374	12.39	48,373

Countries of Destination

1979	United Kingdom	96.6%
	Brazil	1.6%
	France	1.0%
	United States	0.8%
1978	United Kingdom	100%
1977	United Kingdom	100%

these exports of platinum scrap metals went unquestionably to the United States. See Table A2 of the Appendix to this chapter.

The third item on the list involves exports and imports of fabricated materials made of platinum metals which are not listed elsewhere in the Canadian trade statistics. As Table A3 tells, the quantities involved ranged between 0.911 metric ton in 1978 and 1.736 metric tons in 1979 as regards exports. The imports were between 0.684 metric ton in 1977 and 0.748 metric ton in 1978. Accordingly, the quantity balance has been positive although the accounting balance is marginally positive, if not negative, as the year 1978 is concerned. Again, several countries are involved with the United States the chief recipient of our exports, while the United Kingdom is our main source of imports.

The next category refers to specialty types of platinum which come to this country as lumps, ingots, powder and sponge. Only imports are recorded and the quantity has declined from above 10,000 ounces in 1977 to about 7,500 ounces in 1979 (Table A4). However, due to the strong upward movements of prices, the amount payable to these countries almost doubled from $Can. 1,732,000 to $Can. 3,071,000. The depreciation of the Canadian dollar added an additional strain to this balance.

Canada has also been an importer of other refined metals of the platinum group, excluded so far in this analysis. These imported quantities were greater in 1978 than in either 1977 or 1979. However, the amount payable in 1979 exceeded -just like in the previous category -the values of the other two years (Table A5).

Finally, there is the item of 'platinum crucibles', mostly used in chemical laboratories. The imported quantities, as shown in Table A6, are relatively stable around the 22,500 ounces (0.7 metric ton) mark. The values of shipment have been on the rise for consecutive years, matching the example given in the previous import categories. These crucibles came exclusively from the United States.

In short, the balance appears positive for both exported total quantities - assuming rightly or wrongly homogeneity and thus comparability among the different platinum metal substances and products - of contained PGMs and their values. If one includes re-exports of PGMs (Table 6), the financial balance shows twice the value of $Can. 41,000,000, at least for the years 1978 and 1977. For 1979, for which re-exports are not ascertainable at the time of writing, the balance stood at almost 42 million.

Table 6

The Platinum Metals: Trade Balance 1977 - 1979 (in '000 $ Can.)

		1979	1978	1977
Exports				
Item 256-29:	Ores and Concentrates	47,497	55,062	48,373
Item 256-39:	Metals in Scrap	15,115	8,932	3,297
Item 455-29:	Platinum Metals, n.e.s.	7,189	3,741	4,400
		69,801	67,735	56,070
Imports				
Item 455-12:	Lumps, Ingots, Powder, Sponge	3,071	2,600	1,732
Item 455-22:	Other Platinum GMS	3,475	2,043	2,061
Item 455-25:	Crucibles	15,001	6,817	5,627
Item 455-29:	Platinum Metals, n.e.s.	6,256	5,065	3,837
		27,803	16,525	7,630
Overall Balance:		41,998	51,210	48,440
Add Reexports:		n.a.	334	3,180
New Overall Balance		n.a.	51,544	51,620

Whether the final settlements of this overall balance actually enters the foreign exchange market and thus adds strength to the external value of the Canadian currency is a question left for the accounting profession to answer. The problem arises because Canada does not have facilities to refine the PGM on its own soil. The entire mining output of our two main producers - INCO and Falconbridge - is refined outside the country; that is why the exports of ores and concentrates is of that particular magnitude as is evident in Table 5. It also explains why this country does not have an item for the exports of refined platinum on its list! This leads the discussion over to the next item.

PGM Refineries

The number of platinum refineries in the world is small. Mineral Facts and Problems, 1975, reasons in terms of seven or eight.[20] Actually, there are more than that and one should draw a line between two types: there are the large refineries and there are also a number of smaller ones such that the total of most known plants extracting PGMs in one way or another amounts to fourteen. This is the count which one can extract from Mohide. They have been listed summarily in Table 7.

On the base of this evidence, it is fair to say that there are fourteen refineries in the world with an approximate capacity to produce 200 metric tons annually.

Table 7

Platinum Group Metal Refineries in the World

	Country	Location	Company	Source of Supply	Capacity metric tons	Process and comments
	Canada					
1	England	Acton(1924) "1968"	INCO(Mond) Clydach	Sudbury INCO	6.5	20% loss of PGMs in process, also toll-refining possible
2		Brimsdown & Royston(Essex) *)	Johnson Matthey	S.A. Nickel matte	50 oz/mt.f	nickel matte (unspecified)
3	South Africa	Wadeville-Germiston Transvaal	Johnson Matthey		50	
4		Springs Transvaal	Impala Platinum Mines(INCO 10%)		30	supposed to be largest in the world
5		Brakpan, Marikana Transvaal	Western Platinum Falconbridge (24.5%) Superior Oil Lnrho		6.7	
6		Germiston Transvaal	Rand Refinery (world's largest gold refinery)		n.a.(small amounts of PGMs as by-products)	
7	U.S.S.R.	Krasnoyarsk			90 +	

..... continued

*) A new $ 36 million refinery using solvent extraction techniques will be built at at Royston by the Johnson Matthey Research Center.This refinery should be on stream in 1982.(E&MJ,Apr.,81,p.198)

Table 7
(cont'd.)

	Country	Location	Company	Source of Supply	Capacity metric tons	Process and comments
8	U.S.A.	Newark, N.J.	Engelhard Minerals & Chemicals Corp. (Anglo-American 30% interest)		(11)	secondary refining Norwegian is primary although Falconbridge residue of Ont. ores refined here.
9		Malvern, PA.	Matthey Bishop (British parent has control)			
10		Winslow, N.J.	Matthey Bishop (British parent has control)		4	
11		East coast	United States Metal Refining Corp. (Amax)			These three firms recover small amounts from base metal operations.
12		East coast	Asarco			
13		Utah	Kennecott			
14		California	Gemini Industries			

Source: Extracted from Mohide, op. cit., pp. 51-55; and Butterman, loc. cit., p. 837; also 30-40 domestic (U.S.A.) refiners handle or process platinum scrap.

Obviously, Canada does not have any refineries. The two producers of PGMs in Canada are INCO and Falconbridge in Sudbury. Inco sends its PGMs - bearing sludges from its Ontario facilities to the platinum-group metals refinery of its subsidiary, Mond Nickel Co. Ltd., at Acton (London) England. However, during 1978 and 1979, most of INCO's ores and concentrates must have been refined in the United States, as is born out from the statistics in Table 5. Only recently did the company announce its intentions to establish precious metal refinery facilities by the middle of the 1980s in the Sudbury area. The remainder of the shipments not originating from INCO would, therefore, have to come from Falconbridge, although this type of breakdown is not given in our trade statistics.

Falconbridge sends its nickel-copper matte from the Sudbury smelter to an electrolytic refinery in Kristiansand in Norway. The platinum-bearing sludges of these ore substances are then shipped for refining to the United States (Engelhard). However, the gold and silver have to be sold to the Norwegian government; they stay in Norway!

In short, Canada has no refinery for precious metals although it is the world's third largest producer. The reason for this anachronistic situation is, perhaps, more of a historical origin rather than the result of design. Nonetheless, the time may be drawing closer that this situation will change.

The seriousness of the problem is aggravated by the general admission of the fact that 20 percent of the Ontario PGMs are lost in the refining process.[22]

At the same time, it is interesting to know that both Falconbridge and INCO are involved in two South African refineries which they helped to construct. This has also been taken care of in Table 7 (@4, @5).

Economically, it is understandable to build refineries where the platinum deposits are, as long as platinum group metals are the chief output of these mines and not, as is the case for Sudbury, by-products of nickel-copper sulfide ores. This means that the emphasis in Ontario is on the production of nickel and copper in these localities, whereas in South Africa, the output climate is determined by the conditions in the PGMs markets and not in the nickel-copper market.

The largest of all refineries is in the U.S.S.R. at Krasnoyarsk. It is an electrolytic refinery, and according to Mohide and Buttermann,[23] the sludges come from the nickel refineries in Norilsk "and possibly from the other three platinum mining areas."[24] They are shipped to Krasnoyarsk, which is located 900 miles south of the main nickel mining district of Norilsk and Talnakh. The capacity was thought to be 90 metric tons per annum and rising by 4 - 6 percent annually to meet the rising refining demand for platinum output stemming from mounting nickel mining activities.

In the U.S.A., Engelhard Industries, which is controlled by Anglo-American Corporation of South Africa, has the largest and most up-to-date refinery in the United States. It refines primary platinum from the Rustenburg Mine and the Falconbridge anode slime from Kristiansand; it is known for being a toll-refinery, especially in the secondary scrap field as recycling has become increasingly important with the use of platinum as recoverable catalysts. In turn, Engelhard is the world's largest consumer-manufacturer of primary products. In short, the Anglo-American Corporation in connection with Engelhard Minerals and Chemicals Corporation in which it has a 30 percent stake, presents a fully vertically integrated industrial structure. For this vertically structured edifice, Engelhard provides the horizontal penetration of the world platinum markets, as may be deduced from the number of subsidiaries and associates which this corporation has in most industrialized countries.[26]

The other refineries of Table 7 are of minor significance. They are of median and small size and help certain firms to recover the platinum as by-products of their base metal mining operations. For some of these, no capacity figures are given. Nonetheless, they have been included to round out the picture of the world PGM refinery situation.

A similarly interlocking market relationship exists between Johnson, Matthey, In England and in South Africa. In England,

it has a nickel-platinum refinery to process the PGMs contained in South African nickel matte. At the same time, it has a very large refinery in South Africa and runs another two smaller refineries in the United States, in Malvern and Winslow, owned by Matthey Bishop. However, it is fair to say that the market penetration accomplished by Rustenburg Platinum Mining, Engelhard and the Anglo-American Corporation is much more widespread than that of Johnson Matthey.

Finally, there is the Canadian connection. While INCO has its refinery in Great Britain, it is also connected to Impala Mining. Falconbridge, in turn, has customer relations with Engelhard, which refines the nickel sludge coming from Kristiansand. In South Africa, it is engaged with Western Mining in PGM mining. Consequently, South African platinum metal mines are operated by a few firms with a small number of refineries controlled by them; in connection with the Canadian PGM-producing firms they must exercise indisputably an unusual control, not only over the production, but also over the distribution of the metals at the marketing end through London and through New York.

SECTION IV: WORLD PGM RESERVES AND ALTERNATE SUPPLIERS

This section discusses briefly what little is known about the reserves of platinum group metals; afterwards, it gives a presentation of the main alternate suppliers of the metals on a global basis, and finally, it explores some aspects of stocks and inventories of the refined PGMs.

World PGM Reserves

Duncan R. Derry presents a set of diverse figures of world PGM reserves which is based on estimates of the U.S.B.M. 1979 and it is shown as the first (1) reserve figure in Table 8 amounting to 24,570 metric tons of metallic contents. These statistics differ substantially from those produced by U.S.B.M. as given by Butterman, of 1974. His values have been adjusted by including the U.S.S.R., which were not available at that time. The adjusted Butterman figures and the pattern of distribution by country are 41,921.6 metric tons (1974) as set out under column (2) in the same table. In essence, it is a combined estimate of Mohide's and that part of the Butterman Table which is less optimistic; of course, there is another adjustment, for Canada, which is arbitrarily set at 1,000 metric tons

Table 8

World Platinum Group Metal Reserves by Main Country and Distribution

Country	(1) Metric tons	%	(2) Metric tons	%	(3) Metric tons
World	24,570		41,291.6		57,975
U.S.S.R.	6,200	25.2	6,220	14.84	6,220
South Africa	18,000	73.3	6,220	59.64	-
Canada	280	1.2	1,000	2.38	-
Colombia	30	0.1	30	0.07	-
U.S.A.	30	0.1	6,531.6	15.58	-
Other	30	0.1	30	0.07	-
Zimbabwe	-	-	3,110	7.42	-
		100.0		100.0	

because the mining community in Sudbury disagrees with the figures given by Duncan R. Derry. This means that the results obtained are not the outcome of sophisticated estimation procedures. They follow from a personal judgment. Naturally, experts may disagree with this figure, some in the way that it is too high and others in that it is still too low. Geologists generally agree that any statement of a reserve cannot be correct; yet, this does not remove the question. Consequently, a third value has been introduced to satisfy the reserve optimists. It is based on the most optimistic projection of the Butterman Table but adjusted for the U.S.S.R., which is assumed to have been omitted in that estimate. The final total would be 57,975 metric tons, a value which still may not do justice to the Canadian polymetallic reserve, however hypothetical they may be. In short, the reserves of PGM may be 41,921.6 metric tons as the center value of the two in a possible range of between 24,570 in the short run and 57,975 when seen far into the future.

<u>Alternative Suppliers</u>

South Africa	Production 1950:	105,750 ounces	(3.29 metric tons)
	1979:	3,200,000 ounces	(99.5 metric tons)

South Africa is and will be, by any stretch of the imagination, the most substantial prospective platinum supplier. The

metals were first discovered in 1923 in a chrome and sulfide enriched layer with an average mining width of 28 inches which is one of the three layers of the Bushveld complex. The most remarkable of these is the Merensky Reef which has an approximate slope of -9m degrees. This Merensky Reef (formerly called the Lombard Reef) measured an unbelievable strike length of 300 miles around the centre of the entire Bushveld complex.[27] The platinum metals occur in two forms: one is in their metallic state, and the other in sulfides together with copper, nickel and iron, like in the Sudbury Basin in Ontario.[28] Mining is done by underground methods.[29] Below this main deposit is the second which is dimensionally quite similar to the first. A third and thicker layer but of a lower grade is found underneath the second. The zones of interest go thousands of feet into the ground. The magnitude of such a deposit raises, of course, the question of the reserve potential of this huge mineral complex, not only with respect to the three layers, but also with respect to adjacent deposits. The estimates vary from conservative 200 million ounces to the more optimistic figure of 800 million ounces of the metals.

Unfortunately, neither the South African Government's Department of Mines nor the producers are in the habit of publishing precise figures of the output of platinum metals. The values provided by the UN and the ABMS are estimates only, though fairly reliable ones. They refer to platinum metal

ores and osmiridium recovered from gold ores.

From the Canadian point of view, one multinational company of interest is Texasgulf,[30] a firm which is owned one third by the Canadian Development Corporation. This company is engaged in a joint venture with Utah International[31] considering exploration and development of a platinum-chrome deposit adjacent to the Merensky Reef. The word is that Texasgulf will use a new smelting technique, EPP - for Expanded Precessing Plasma Process.[32] In this fashion, Canada could partake more directly than through INCO and Falconbridge in the recovery of PGMs and chrome in South Africa. The actual reserves of this deposit remain, essentially, unknown.[33]

Furthermore, Impala Platinum of South Africa is investing $153.4 million in a plant to process 1,050,000 ounces of PGMs, or 32.7 metric tons. This substantial expansion is planned to be in operation by 1982.

Moreover, Western Platinum of South Africa has started an expansion program of a mine to increase annual output from 135,000 (4.2 metric tons) to 245,000 (7.6 metric tons). This project should be completed by 1982.

There is no doubt that all these projects will assure South Africa its dominating position as the world's largest platinum producer.

U.S.S.R. Production 1950: 125,000 ounces (3.9 metric tons)
1979: 3,200,000 ounces (99.5 metric tons)

In terms of international exports, the U.S.S.R. holds 20 to 25 percent as its share of that exports market, a large amount of which is destined for the United States, especially platinum. In addition, the U.S.S.R. has supplied half of the world's consumption of palladium and rhodium, although, in recent years, this supply has tapered off to some degree. However, it is normally expected that the U.S.S.R. will increase its output of the PGMs at a rate of between 3.5 and 5.5 per annum in continuation of the approximate past range of increases for the years 1975 to 1979.[34] However, output could rise faster.

Similar to the source of silver, platinum comes chiefly from the Norilsk and Talnakh copper and nickel complex in Krasnoyarsk Kray and from the Severonikel and Pechenganikel complexes in the Kola Peninsula. There are also some placer deposits in the Urals, the historical origin of Russian platinum. No doubt, the Norilsk occurrence is the most important one as it supplies 75 percent of the PGMs of the U.S.S.R.

In the year 1975, the PGM output of the U.S.S.R. amounted to 2,650,000 troy ounces with 1,987,500 ounces coming from the Norilsk complex. The mineral production plan for the area was to increase platinum output by 80 percent by the year 1980.

This would correspond to an approximate annual production increase of roughly 10 percent in terms of the total PGM output in the U.S.S.R. Assuming the output of other sources to contribute 1.2 percent, the expected-planned expansion would have a production rate increase of 11.2 percent for a target. However, increases in the actual output rate remained at only 5.18 percent during those years (between 1975 and 1980). The reason for this unplanned low performance was that, in the opinion of one source, construction had been behind schedule. There was, for instance, the Nadezhada plant at Norilsk. At first, it was to be completed in 1975, then in 1977, finally it was to be completed in 1980. One has also to bear in mind that the output of platinum will rise when the Oktyabr underground mine and its No. 2 concentrator will be finished at the same time as the first stage of the Nadezhada smelter. This six-stage mine development started in 1969 with a target year of completion in 1980. By 1978, four stages were finished and the last two stages were in progress. Regrettably, it is not possible to verify whether or not the operations are now on target; but sooner or later, they will be. This means that, for the years ahead, the platinum output of the U.S.S.R. may accelerate world production by about 5 percent. This is larger than initially envisaged and has to be kept in mind as a possibility which cannot be discarded off hand.

The greatest impact of this expansion in PGM output will be felt by palladium. This metal occurs in the group at a ratio of 2:1 of palladium to platinum. Therefore, volume of palladium output will make the U.S.S.R. the world's largest source of this noble metal. In addition, this strong occurrence may also explain the recognized and better fineness of marketable palladium sold in Western markets by the U.S.S.R. in comparison to the products of the Western refineries. It also means that this better quality is not necessarily the result of more sophisticated metallurgical technology applied in the U.S.S.R.[37]

Consequently, the increases of the rate of output of PGMs in the U.S.S.R. will be much greater than normally is expected as it is geared to the continuously rising domestic recovery of nickel-copper ores, with which the PGMs have to keep pace.

U.S.A. Production 1950: 37,855 ounces (1.18 metric tons)
1979: 7,300 ounces (0.227 metric tons)

There is a very important fact which should not be underestimated in its implications on the demand for industrial consumption of PGMs in the United States. The point is that this once so important primary producer of PGMs has to rely on imports and to a considerable degree on the recycling of old scrap. For instance, in 1978, the U.S.A. industries consumed a total of 1,169,621 ounces of platinum and 950,292 ounces of other PGMs mainly in the form of palladium.

In the year 1966, the primary production of platinum stood at 30,000 ounces and at 31,300 ounces of palladium. Secondary production was 49,600 ounces of platinum and 50,000 ounces of palladium. By 1974, the primary production stood at 4,103 and 8,634 ounces of platinum and palladium respectively. In that year, secondary output was 96,000 ounces and 214,400 ounces for platinum and palladium respectively. By 1978, total primary and secondary output dropped to 70,500 and 151,400 ounces correspondingly for both these metals.

When iridium and the remaining platinum group metals are included, the following picture develops.

Year	(1) Total Primary & Secondary production of PGMs		(2) Industrial Consumption	(3) [(1):(2)] x 100
	ounces		ounces	%
1966	176,936		1,657,795	10.6
1974	338,450		1,981,010	17.1
1978	235,619		2,119,913	11.1
		Platinum		
1966	79,611		665,941	12.0
1974	100,102		943,689	10.6
1978	70,510		1,169,621	6.0
		Palladium		
1966	81,376		882,192	9.2
1974	222,050		886,063	25.1
1978	151,428		816,840	18.5

These values show how much of the PGMs were produced in those particular years and the amount demanded by the industrial consumers in the United States. The degree to which United States consumption was satisfied from domestic sources is given by the values in column 3 which demonstrates clearly the dependency of the United States on platinum metal imports from the outside world.

To summarize the critical point for the United States: it produces 0.1 percent of the world platinum as primary output but consumes 18.5 percent of the world primary output, which is 185 times more than its mines can produce. When the secondary production is included, the United States absorbed 16.3 times more platinum than it was able to produce. From this point of view, the United States is excluded from becoming an alternative supplier in the near future, although prospects may be somewhat different if one looks further into the future.

At first, this critical import dependence has been recognized by the new administration which has placed the PGMs among the priority items of the United States strategic stockpile.[38] Considering also that, at one time, the U.S.A. had been a significant supplier of the metal on a world basis and that it is now forced to import platinum group metals from the U.S.S.R., then the question arises whether the U.S.A. has any sizable mineral reserves. To the extent that Table 8 has provided an answer in the affirmative and here are the reasons why:

According to Butterman's Table, there are about 777 metric tons of PGMs identified in Alaska, of which 4 percent can be called actual reserves, or about 31 metric tons.[39] There is also a small placer deposit at Goodnews Bay, Alaska, and in addition, the hypothetical reserve, as Butterman calls it,[40] is believed to be 1,088.6 metric tons in Alaska.

To these actual and hypothetical orebodies has to be added a very important source in Montana: The Stillwater Complex. One actual deposit has been recognized. It is located on 110^{o} longitude west, close to Livingston, MA. A main deposit is owned by the Johns-Manville Company, which started exploration in 1967 in an area of great geological affinity to the Bushveld complex of South Africa. Until 1977, this company had invested about $7 million in exploring this property. H.K. Conn came to the following conclusion:

> Conclusion
>
> The ZOI* horizon in the Banded Zone of the Stillwater complex constitutes an important deposit of platinum-group metals. The ZOI appears to be essentially continuous along 39 km of strike length and is typically 1.8 to 2.1 m thick. The grade of mineralization exposed in the exploration adit averages 14.7 g/t Pt + Pd and 0.15% Cu + Ni across 1.9 m and over a strike length of 657 m. In another locality, an average grade of 22.3 g/t Pt + Pd is indicated by diamond drilling across a width of 2.1 m and along a strike length of 5.5 km. The average Pt:Pd ratio is 3.5. These grade are 2 to 4 times those typical of the Merensky Reef in the Bushveld complex of South Africa.[41]

*ZOI = zone of interest

At first, it had been expected that, by early 1980, an announcement would have been forthcoming as to the actual start of operations by Johns-Manville. However, in the meantime, some other events have taken place which will delay a production decision at least until 1983. A new company has been formed: Stillwater PGM Resources. This is a joint venture of Johns-Manville Sales Corporation and Chevron, U.S.A. Incorporated.

In the same area, Dewey Whittaker, an independent operator from Seattle is also exploring the neighbouring area for PGMs. In addition, there is the Anaconda Corporation which, further east, is exploring the Bear Tooth District of Custer National Forest, north of the Yellowstone National Park. This company has already sunk an exploratory adit of 3,000 feet, which it intends to extend by another 2,000 feet. In all, the number of participants in this new mining camp is now much larger than several years ago. In particular, financially strong corporations are involved such that there will be no doubt about the success of the operations. At present, environmental impact studies are being carried out for the PGM and Whittaker proposals. After the environmental hurdle has been passed, it will be around 1983 that a decision can be expected, whether to go ahead with the opening-up of the property of PGM. If the decision is in the affirmative, then the operations would envisage an ore throughput of 2,000 st/d (short tons per day) delivering 60 short tons of concentrates. This concentrate would be trucked straight north to Big Timber - 110° west and Highway 191 - where a smelter is to be constructed. However, there is no mention where the metal is going to be refined![41a]

Since the size of the orebody has not been stated explicitly, the actual reserves cannot be determined. However, Butterman speaks of a hypothetical deposit of 4,665 metric tons of PGMs in 1974 and, therefore, there can be little doubt that

this hypothetical orebody has moved very closely to the realm of the economically possible.[42]

Consequently, the U.S.A. has much more actual reserves than the Duncan R. Derry statistics suggest (Table 8). This is also indicated by Mohide's estimate of an annual output rate of 27 metric tons for the Stillwater complex[43] even if this seems to be somewhat optimistic in light of an expected throughput of 2,000 st/d with at least 14.7 g PGM/t.

In short, there is sufficient evidence to argue that it is possible for the United States to be less dependent on imports of the PGMs because of the PGM high-grade resources at the Stillwater complex

Potential Other Suppliers

Besides South Africa, the U.S.S.R. and the United States, the question arises whether there is a real possibility that other, alternative suppliers of PGMs may enter the scene. The answer is cautiously in the affirmative. As it is realized that the future output of platinum group metals will go hand in hand with the expansion of the nickel and copper mining, all present and future mining countries of nickel and copper sulfides are candidates of supplying PGMs, even if on a toll-refining basis.[44]

The candidates included, above all, Australia, which will become an ever and ever more important supplier of nickel,

and thus of PGMs. Then, there is Yugoslavia. It too has to be included in the nickel-copper sulfide producers. Finally, the Philippines likewise work on the expansion of base-metal mining. Although the present output may only be of marginal significance, all three together will not fail to feed increasing amounts of the PGMs into the world platinum metal marketing system. As time progresses, these total contributions by these candidates may become significant.

Other Sources

Canada

Canada has to be discussed briefly in light of Table 8 (column (1)) which assigns to this country a PGM reserve of 280 metric tons. Since this platinum has to come from the huge nickel-copper sulfide emplacements of the Sudbury Basin, it would imply that, at an annual output rate of 10 metric tons of PGMs, the Sudbury Basin would be exhausted by the end of the century. This is highly unlikely! Since the magnitude of the Sudbury orebody is just as unknown as the U.S.S.R. PGM operations are mysterious, there is, however, certainty in two respects: one is that the orebody is huge and not completely delimited; and second, that sometime far in the future, most probably far ahead in the future of the 21st century, this orebody will be exhausted. From this follows that the platinum reserve is larger than Table 8 (column (1)) suggests, and that

this rich storehouse of ores will last longer, especially if pollution restrictions in the area can only be accomodated by a reduction in the rate of output of sulfide ores.

Another point is that there are additional platinum deposits in Northern Ontario. They will be analysed in the engineering part of the study.[45] The literature refers to the Lac-Des-Iles Complex north of Thunder Bay. This area has shown mineralizations of copper-nickel-iron sulfides containing PGMs, especially palladium.[46] Apparently, three companies have studied this zone: Texasgulf, Gunnex and Boston Bay Mining.[47]

In addition, Ontario has another potential source of minerals containing PGMs. The source is coal, in which platinum can be traced. The area which has to be carefully investigated and analysed are the Onakawana Lignite deposits. Indications are - although not entirely conclusive - that a certain amount of platinum is contained in the deposits. Significant traces of platinum appear to have been observed from the ashes, among a list of other elements. Unfortunately, that is all that can be said at this point in time, as further studies have to be undertaken to determine the occurrence beyond any doubt.[48]

Stocks and Inventories

Government authorities, dealers and merchants and private individuals are known to hold PGM inventories. The superpowers -

the U.S.A. and the U.S.S.R. - hold strategic stockpiles of PGMs to serve the defense needs of those countries.[49] There does not seem to be anything unusual in the existence of all these stockpiles which make up 87 - 90 percent of the annual world output of these metals.[50]

Both the U.S.A. and the U.S.S.R. hold fairly sizable quantities chiefly of platinum and palladium, although in the U.S.A., the objective is greater than the actual stock. Dealers too hold inventories as do the producing mining firms. Their stocks may be necessary to serve the market, especially when it is susceptible to upwards movements of prices. However, the industry has not always acted as the economic rules say they would. For instance, during periods of soft demand and declining prices, inventories would normally rise, while during periods of upward moving prices, inventories would be depleted.

This has not been the case. It cannot be taken lightly when an expert in the commodity trading field such as Mr. Mohide tells of the story that "Rustenburg had a large inventory - said to have been 62 metric tons of platinum - in 1972, while it was increasing the platinum producer prices."[51] In short, Rustenburg was strong enough to maintain and raise existing prices instead of selling from inventories and reducing prices. Only imperfect competitors who are not exposed to the threat of retaliation can act in this non-competitive form.

In turn, it is also obvious that the U.S.S.R. has withdrawn from supplying the market with platinum. This happened in July and August 1977, when the Russian started to be absent from the platinum market. By leaving the market to the strongest producer of platinum, the largest producer of palladium - viz. the U.S.S.R. - still had an assured market in New York. One speaks of an almost formidable palladium stock in the hands of the Russians which overhangs the market, which at one time seems to have depressed the palladium prices. Nonetheless, the market has not been flooded by the Soviet Union.

In the meantime, however, a new type of participant has made itself at home in this market of the noble metals. In 1979 and early 1980, the private investor/speculator appeared in the PGM market. Driven to find a hedge against the devaluation of money through inflation, the private sector started to absorb physical quantities of refined metals and the platinum metals were forced to adopt a monetary-storage function formerly exercised mainly by the precious metals of gold and silver. According to Ian Greig, former Chairman of Impala Platinum Ltd., 330,000 oz - or about ten metric tons - went into private hoards in 1979, and more so at the beginning of 1980, an amount which introduces an unusual uncertainty into the market. Writes Ian Greig: "The worrying question is when these nameless, faceless buyers will enter the market as sellers."[52]

This seems to indicate that the larger suppliers had the market for themselves. It is also strange that the man does not worry at all about the much larger stocks of the U.S.S.R.

The additional stockpile now in the hands of the speculators/investors does nothing but raise the total inventories to almost 100 percent of annual output capacity. Consequently, this situation is much less critical than in the case of the gold and silver inventories, where the huge hoards may build up storm clouds over the market!

SECTION V: FUTURE PRICES AND PRODUCTION OF PGMs

Introduction

This section is an attempt to appraise the future of the platinum metal, and by implication, that of the metals of the group. This is done with the available information which is limited due to the imperfectly competitive nature of the PGM sector.

At first, historical prices will be reviewed dealing mainly with the history of prices posted by the major producers. In addition, relationships between market (dealers') prices and those posted prices will be explored. In this connection, interest centres on the close tie that exists between the major producers in South Africa, i.e. Rustenburg and Impala, the dealers and the platinum-metals consuming industries which seem to go beyond the customary - not to say competitive - trading relationships. Obviously, proprietory links do exist which cannot fail to produce the orderly market mechanism which is the pride of the industry.[53] One point has to be kept in mind at this juncture: the supply price quoted by the major producers is always below the dealers' and the free market price. When demand pushes prices up, the producers may be

inclined to follow this move after a period of time to raise theirs as well. Should the free market price dip below that of the producers' floor price, then the producers must adjust the floor also in a downward direction. That is why the inventories of platinum metals must cause concern in the head offices of the major producers since the actions by the private holders of the metals appear unpredictible.

A short outlook on production (and demand) follows. Here, the interest is directed toward the output of the entire group of PGMs for which the price of the main metal - platinum - is, due to the lack of a proper PGMs price index, a representative surrogate.

Prices

Historical Prices

In the period between 1950 and 1964, a relatively stable price trend can be recognized for platinum. It certainly had its ups and downs, but there was nothing extraordinary in its overall behaviour. If anything might have been unusual, then, it was the drop from \$103.97/oz in 1956 to a low of \$66.68/oz in 1958. This swing, as may be seen in Exhibit I, with a high and a later low, could be simply interpreted in the sense that the latter was the necessary reaction to the former, indicating a relatively high sensitivity of the users to high prices. It

Exhibit 1

Platinum Price (Major Producers') for the Years 1950 to 1980

in current $ U.S.

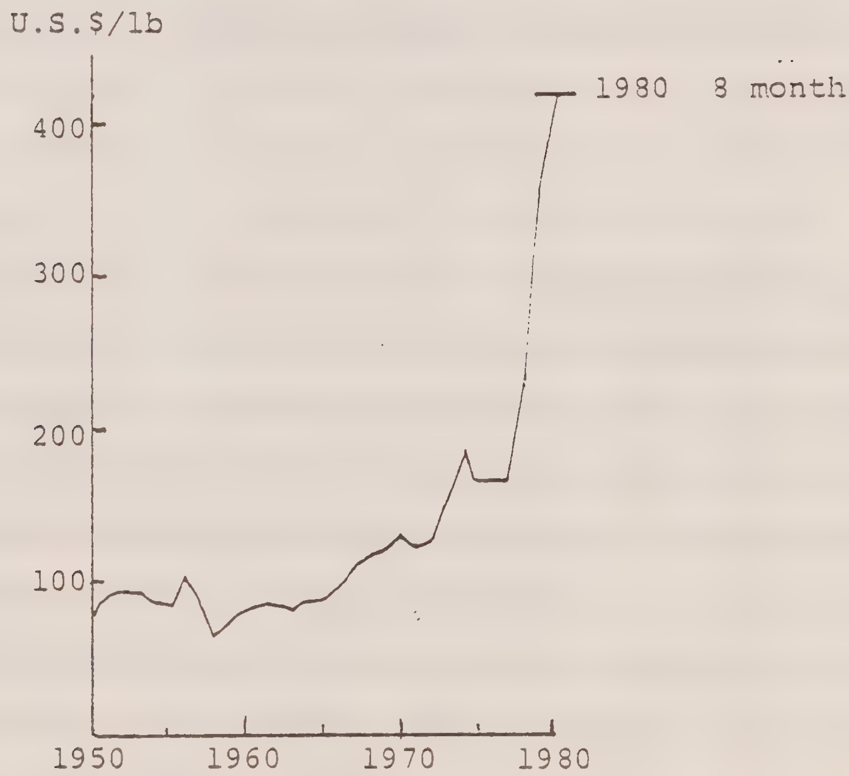


Table 9

Platinum Prices 1950 - 1980 in $U.S./lb

1950	77.68	1966	99.47
1951	91.50	1967	110.25
1952	94.58	1968	117.00
1953	91.90	1969	124.18
1954	86.16	1970	132.50
1955	85.06	1971	123.04
1956	103.27	1972	127.13
1957	90.49	1973	152.18
1958	66.68	1974	184.98
1959	74.59	1975	169.87
1960	83.21	1976	168.39
1961	83.50	1977	167.71
1962	83.50	1978	237.08
1963	80.93	1979	352.33
1964	88.48	1980	420.00*
1965	98.04		

*1980 8-month average with no change in any month over that period, although the November and December prices were at $475.00

is also interesting to note that, historically, the price of platinum has always been substantially above the price of gold, which, for those years, was still fixed.

Starting with the year 1965, a steady upward trend became clearly noticeable. This steadiness lasted until 1977. From then on, the price ran practically away, ending at $352.33/oz in 1979 and at $475/oz for the last two months of the year 1980. This upward rise in the producers' price was in reaction to the suddenly changing sentiments in the free market and not a result of economic cost realities. Even if the producers, reaction occurred after much reflection on the effect which the increases in prices might have on the price-conscious industrial users such as the automotive industry and the Japanese jewelry industry, the producers had to adjust their quotations considerably towards the higher levels of free market prices.

When, finally, in the first week of March of the year 1980, the free market price of platinum reached $1,047/oz, it set a historical record. However, the Rustenburg published price for the metal still stood at $420/oz, which was substantially below the high-flying values in the market for consumers, dealers and investor/speculators.

The reason for this exceptional increase in the free market price was a result of the pressures and anxieties which emanated from the political and financial-monetary scenes of the world.

What had been true for gold which had always been the measuring rod of the values of domestic currencies, had suddenly spilled over into the platinum theatre. Irrational, speculative fever now put platinum through the paces, pushing it to unheard-of heights. After the unavoidable return to some type of normalcy, it was a surprise to find that the price of gold remained above the platinum price. The historical pattern which had seen the price of platinum stay much above the price of gold had been broken. It remains, of course, a very interesting though unanswerable question, whether this reversal of the fundamental price relationships between these two metals is going to be permanent to establish a new historical pattern. In light of the actual behaviour of the price of gold in the market and the forecast for the gold until 1990, it would appear that the historical differences will largely disappear as the prices of the two metals presently are approaching parity.[54]

The sudden price eruption occurred in light of specific conditions on the supply side supporting the upward movement. At that time there was a substantial demand for platinum in the United States. This consumption demand, coming from the fibre glass industry, oil refining and from the automotive industry for the production of emission control devices, could not rely any longer on the supply from the U.S.S.R. which had substantially curtailed exportation of platinum. Reduced

availability from this important world source and the impact of the lengthy INCO strike from August 1978 to June 1979 led to considerable shortages and thus to increased upward pressures on platinum prices. It is, therefore, understandable that the price had to go up. However, it is not at all surprising that the market price did not stay that high nor that the producers' prices did follow the general outburst hesitatingly, carefully, but consistently.

Future Prices

According to the econometric forecast, platinum prices posted by the producers given in constant 1979 $ U.S. will be rising slowly. As shown in Table 10 and Exhibit 2, the price of platinum ought to have been $319.96/oz for the year 1980, with a decline predicted for 1981 and 1982. Afterwards, platinum prices would rise steadily and by the year 2000, they would have increased by 87 percent over 1979. By the year 2004, platinum would be sold by the producer for $705.46/oz.

This projected behaviour is not yet fully born out by reality to judge in the light of the platinum prices as they unfolded during 1980 and so far in 1981 and it is too early to pass any judgment on the projection. It should not be forgotten that the model behaved very well before 1978 as brought out by the simulation study.[55] The main argument is that the model reflects the economic cost realities facing the producers and

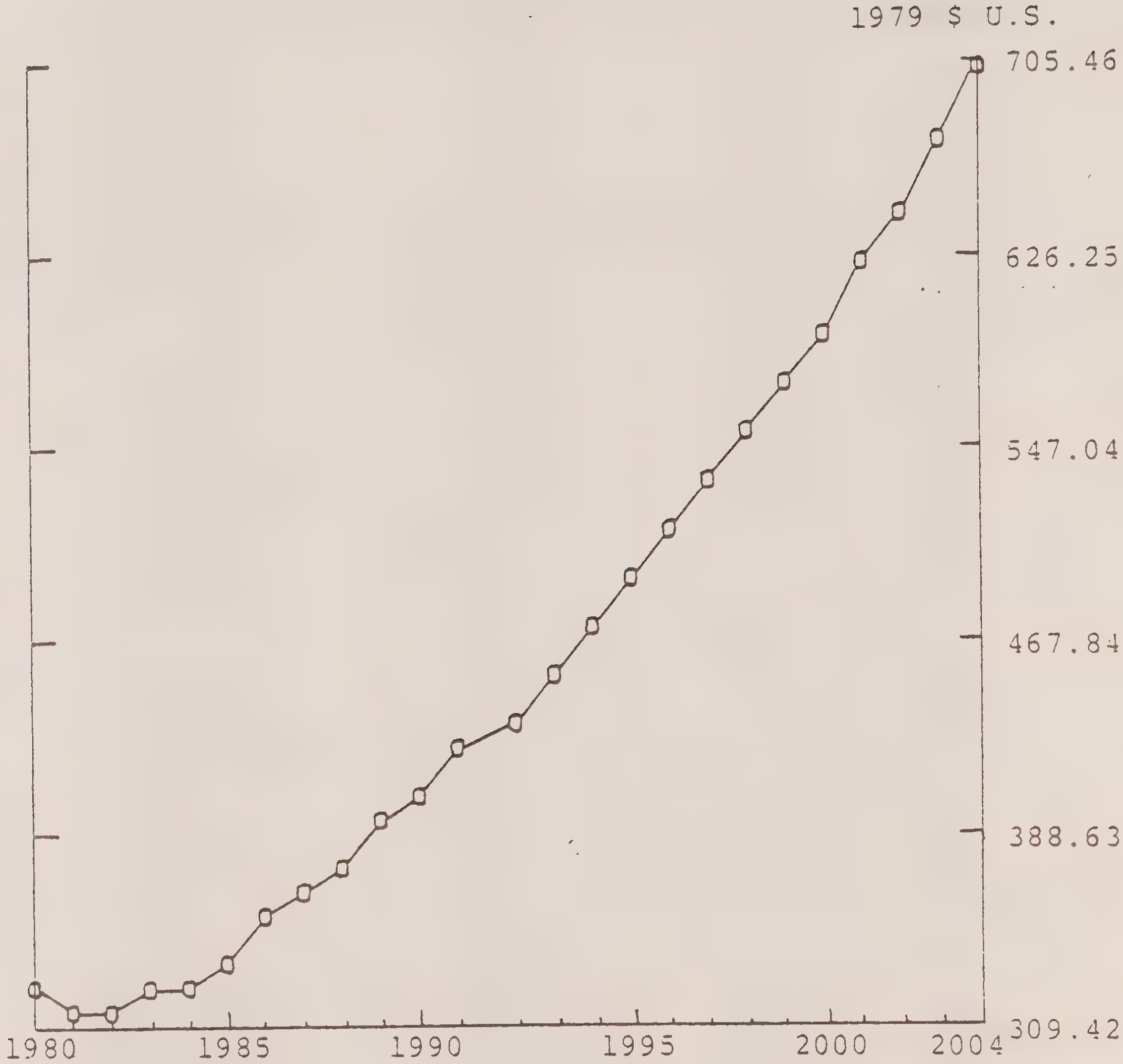
Table 10

Future Platinum Prices in Constant 1979 $U.S. and Supply (and Demand) for Platinum Group Metal in ounces and metric tons

Year	Price $/troy ounce	Supply (=Demand) metric tons	ounces
1980	319.96	246.4	7,921,300
1981	309.42	273.3	8,787,180
1982	309.54	295.0	9,485,260
1983	315.23	315.7	10,149,329
1984	324.01	337.3	10,844,281
1985	334.62	360.7	11,598,158
1986	346.43	386.4	12,421,982
1987	359.15	414.3	13,319,927
1988	372.62	444.6	14,294,074
1989	386.82	477.3	15,346,462
1990	401.73	512.6	16,479,843
1991	417.37	550.5	17,697,888
1992	433.78	591.1	19,005,160
1993	450.99	634.7	20,407,031
1994	469.04	681.5	21,909,593
1995	487.96	731.5	23,519,598
1996	507.81	785.2	25,244,423
1997	528.63	842.7	27,092,057
1998	550.46	904.2	29,071,107
1999	573.35	970.1	31,190,822
2000	597.36	1,040.7	33,461,122
2001	622.53	1,116.4	35,892,188
2002	648.90	1,197.3	38,494,795
2003	676.52	1,284.0	41,280,477
2004	705.46	1,376.6	44,261,614

Exhibit 2

Platinum Price in Constant 1979 $ U.S. for the Years 1980 to 2004



that political and world-financial disturbances superimpose themselves over the basic economic structure. If anything may be deduced from this discrepancy between economic and market conditions, then,it is that the producers, by shifting their prices up along the performance in the market, were permitted to reap substantial rent components, which will disappear as time passes on.

Supply

The long-run outlook for the supply of the PGMs appears at first to be highly disturbing. As Table 10 and Exhibit 3 demonstrate, a very large increase in the output of the PGMs is predicted in the future. By the year 1987, according to the econometric model, the output should reach 400 metric tons. By 1998, the 900 metric tons mark will be reached annually and 1,041 metric tons would be produced by the year 2000. At the end of the forecast period, predicted annual output would stand at 1,377 metric tons.

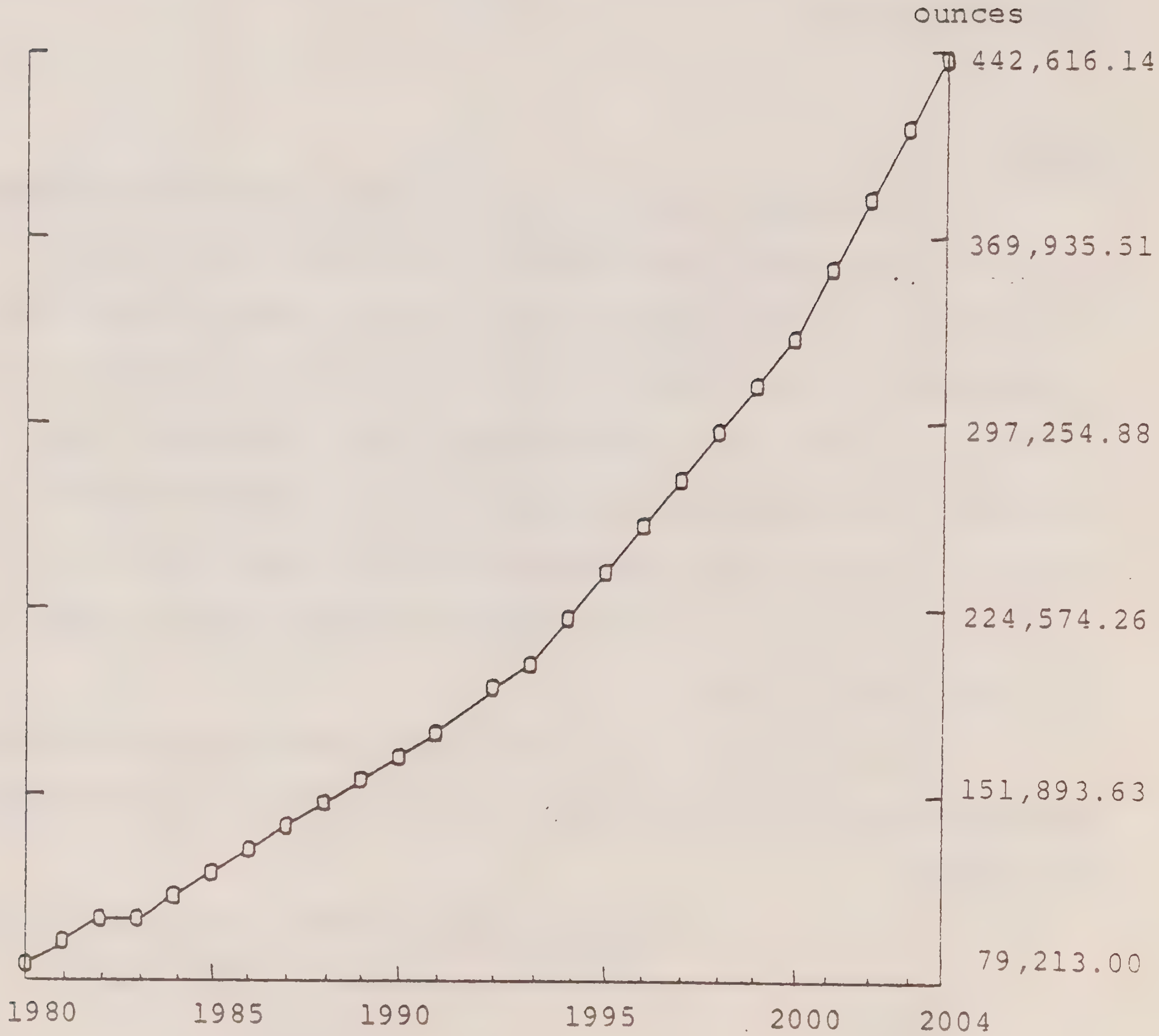
The cumulative output would make substantial inroads into the known reserves of the PGMs. It is given by the following breakdown.

By Year	Cumulative Exploitation of Platinum Resources in metric tons
1985	1,828.4
1990	4,063.6
1995	7,252.9
2000	11,795.8
2004	16,770.1

Exhibit 3

Supply and Demand for Platinum Group Metals for the Years 1980-2004

(ounces)



This projection would indicate that by the year 2000 48%, 28.6% and 20% of the short, medium and long-run reserves would have been exploited.

Admittedly, this forecast does not stand up as well as the others against forecasts undertaken by authorities in the field, as for instance, by Malenbaum,[56] Mohide,[57] or Butterman.[58] The different predictions for the year 2000 are (in metric tons):

	E. Willauer	Malenbaum	Mohide	Butterman (1974)
in metric tons	1,041	436.4	178.5 (Pt only)	342.8
			400 USBM	257.1-457.2

An apparent consensus seems to exist among the other projections of the volumes of production. By 2000, the output will be around the 400 metric ton mark. The econometric prediction is therefore above the general benchmark by a factor of 2.4. Such a large discrepancy requires some explanatory comments. A brief look at some of the interesting aspects in connection with the other forecasts should serve that purpose.

There is, at first, Mohide's projection and he makes some very interesting and pertinent comments in reference to pronouncements by two chairmen of the two larger platinum producers.

> The Chairman of Johnson Matthey and Co. Ltd. said...that rapid industrialization by the developing nations will lead to a heavy demand for platinum metal and related technology implying that PLATINUM SUPPLY WILL NOT BE SUFFICIENT TO MEET WORLD DEMAND IN THE FORESEEABLE FUTURE.[60]

He continues in reference to the Chairman of Impala who is reported

(1978)"to have said that a real shortage in the near future is possible".[61]

Furthermore, Mohide thinks that the growth of demand until 1980 would be 10 percent and thereafter, it would decline to below 8 percent. Were one to calculate an 8 percent rise through to the year 2000, total demand for all PGMs would be 965 metric tons; this, in itself, would present only a relatively small difference to the predicted value in question.

In this context, it is again important to point out that one of the underlying conditions is a GDP growth rate for the total world. Should that rate turn out to be smaller than expected, demand and supply for the metals would also be reduced. This is an important factor in analysing the prediction of the econometric model comparatively to the projections by others.

With respect to the Malenbaum prediction of October 1977, it has to be pointed out that his are revised figures. The revision stemmed from a very valid recognition that the intensity with which metals are used in terms of a unit of GDP tends to decline over the long run in any economy. The metal usage is in the habit of maturing with a growing economy. In this fashion, Malenbaum saw himself forced to alter an earlier prediction. There is no reason to dispute the general validity of this argument which the econometric model establishes automatically However, it has been observed that the PGM demand comes in response to

technological innovations, and that it is technical progress which increasingly draws on the faculties embedded in these metals. They are the vehicles of technological change and, as we progress scientifically, their use may be expanded at an increasing rate. Once they have been in place, it is only the imperfections in the market which lead to high prices for the metals and, thus, usher in the unavoidably strong substitution process. Consequently, the forecast output by the year 2000 may quite well be less than predicted, but technological progress will place increasing demands upon these metals, such that the actual outputs in the future must be larger than Malenbaum predicted. However, it is difficult to say how large, due to the innate structure of the PGM from mine to market. And one point is certain: The U.S.S.R. will not fail to raise its output until 2004!

SUMMARY AND CONCLUSIONS

Platinum and the metal in the group which bears its name are the noble metals. They are used in jewelry, have a monetary storage function, and display unusual chemical and physical properties. In a variety of fields, these metals are used as catalysts, especially in the automotive and chemical industries as these modern metals find increasing application through technological innovations. One great potential rests in their use in fuel cells. However, their impressing and exclusive chemical qualities pose serious and complex metallurgical problems for the mining industry.

The consumption of these metals is rising with the United States the greatest, though import-dependent, consumer. It is the greatest consumer in all areas of application except in jewelry. This sector has to be handed over to Japan which developed the most outstanding platinum jewelry industry in the world.

The production of these metals is to 96 percent shared among South Africa and the Soviet Union, with Canada far off in third place. South Africa produces 3.7 times more platinum

than palladium whereas the U.S.S.R. mines twice as much palladium than platinum.

Two firms in the Sudbury Basin of Ontario, Canada, viz. INCO and Falconbridge Nickel Mines, are the Canadian suppliers of mined PGMs. These two firms have also vital interests in South African platinum mines. Canada is a net exporter of PGMs which is mainly due to the exports of all of its platinum ores and concentrates for refining purposes since it does not have a PGM refinery.

There are only eight major refineries on this earth, with one additional to be built in South Africa by Texasgulf and another one finally contemplated for the Sudbury Basin. This is the prospect after fifty years of off-shore refining at a metal loss of 20 percent.

The refineries of importance are located in South Africa, the United Kingdom, the U.S.S.R. and the United States. It is the firm of Engelhard Minerals and Chemical Corporations in the United States which also is the greatest manufacturer of platinum products.

Opinions of world reserves differ in a sense that one estimate provides for a resource of 24,570 to 31,570 metric tons, while a second and larger one centres around 41,921.6 metric tons. The third and most optimistic would envisage a total of 57,975 metric tons. All these figures are open to dispute.

The distribution of these reserves sees South Africa at the top followed by the U.S.S.R., the United States with Alaska and the Stillwater complex, Canada and, then, Zimbabwe. However, these reserve estimates for the individual countries, especially for Canada, are highly suspect. The realities of the Ontario and Manitoba nickel sulfide deposits offer a greater scope of occurrence than is expressed in the lowest of the three estimates.

While South Africa extracts PGMs from its famous Merensky Reef where platinum is the predominant metal, all other countries such as the U.S.S.R., Canada, Australia, the Philippines and Yugoslavia, recover their PGMs as by-products from the mining base metals. Therefore, the future output of PGMs in the world is to 50 percent related to the expected ore grades and quantities of base metals mined, especially nickel and copper. This again places the U.S.S.R. into the forefront of the PGM producers.

Other reserves are known to exist in the U.S.A., Canada - and Ontario for that matter - which may be exploited some day in the future. However, there are also other sources for PGMs than the conventional metal deposits. These sources lie in the background from the active metal-mining scene. Coal is such a medium which may contain platinum among other elements. In addition, one should not forget the general cosmic dispersion

of platinum minerals, which occur in Ontario and in other regions but are too lean for exploitation.

Certain inventories are held in a number of countries for strategic (defense) purposes while recently, investor/speculators and wealth holders have entered the markets as buyers. The PGM industry seems to be apprehensive of these private stockpiles which amount to but 5 percent of annual production, and less of the more formidable reserves stocked up by the U.S.S.R., especially in palladium.

The future competition of real platinum prices are predicted to rise not very dramatically, whereas the predicted output is forecast to increase by much more than other forecasts venture to say.

The following conclusions can now be drawn. The noble metals are vehicles of technological progress and their total consumption is bound to rise beyond 400 metric tons produced by the mines in the year 2000. In comparison to other metals, the use of the PGMs is small and will remain small. In light of the various reserve estimates, there will be no shortage in the foreseeable and the unforeseeable future. A relatively small output combined with unusually complex metallurgical problems in refining of these metals has left the world with a very small number of refineries in supply-oriented (South Africa and the U.S.S.R.) and in market-oriented locations (United Kingdom and the United States). Historical incidence

or not, Canada has no refinery even if it is well endowed with the mineral resource. This stems from a law which is as clear in its purpose by compelling the mining claim holder to refine the ore in the country as it is in the profusion of its exemption.

In contrast, the other countries have tightly knit organizations such that in the nationalsitic context, world production of platinum metals is dominated by a joint-produce duopoly of the U.S.S.R. and South Africa, where the former is the world's largest producer of palladium and the second largest of platinum. The converse holds for the latter, which is the largest producer of platinum proper and the second largest of palladium. Canada is down in third place as a miner of platinum ores only, even if the export balance appears to be positive.

In terms of the market structure of producers, manufacturers, dealers and consumers, all-enshrouding secrecy speaks for a highly imperfect operation , especially since on the supply side, only six large producing firms tie up the main ore-producing countries of the Western world. These firms are themselves interlocked with the major manufacturing firms and dealers in the United Kingdom and the United States. All these firms are very able to comply harmoniously with their posted prices. It is these firms which have control over the refineries which are the keystone of the industry.

There is no apparent threat of destabilizing market operations by the U.S.S.R., the other national duopolist; and why should there be? The U.S.S.R., a horrifying industrial-military complex, will maximize combinedly its return in the foreign markets by selling at a price convenient to the U.S.S.R., while, at the same time, it will increase its strategic reserves in palladium, a very important metal in electronics. Why should the U.S.S.R. reduce its stockpile and force prices down and thereby possibly reduce its return as well as the return of its competitors? For the benefit of the Western users? There is no reason to expect that the Russian will, barring exceptional foreign exchange shortages on the part of the U.S.S.R., destabilize the market. That is why the apprehension of the industry centres on the nameless, faceless investors and speculators which remain outside the oligopolistic market control of the major producers, including the U.S.S.R.

Generally speaking, the supply side from mine to market is dominated by the apparent linkage of the PGM producing mining firms to the distributing and main manufacturing in the United Kingdom and in the United States; and it is without doubt that the refineries controlled by these participants play an instrumental role in making this supply side as effective in producing an orderly but flexible market mechanism.

The econometric analysis, therefore, had to produce a larger output (at lower prices) than projected by other authorities in the field because it assumed a competitive market structure. The world will see a somewhat smaller quantity of PGM produced than this forecast envisaged, which, however, will be larger than the other predictions: because the PGMs are the vehicles of technological progress in certain important industrial areas. To the extent that prices will be forced more quickly into higher ground, one is not far off to predict that many of the users will be forced into early substitution for cheaper processes, if that is possible. In order to increase the supply in the Western markets, it is of critical importance to have more companies with more refineries involved in the production and marketing of these metals.

NOTES

1 The scientific symbol for platinum is Pt; it has an atomic weight of 195.2, and a specific gravity of 21.4. Its melting point is 1,710° Celsius.

2 In small quantities, it is found in what is called sperrylite, which is platinum arsenide - Pt As_2; the mineral in pure form would contain 56 percent platinum; traces of rhodium and antimony are also present. See also J.H. Crocket, "Platinum-group elements in mafic and ultramafic rocks: a survey," Canadian Mineralogist, 1979, pp. 391-402; and pp. 889-890.

3 The metals of the platinum group are:

Light-platinum group:

a) rhodium; symbol Rh, atomic weight 102.9, specific gravity 12.2; colour grayish-white. Special qualities: insoluble in acids, hard to fuse.

b) ruthenium; symbol Ru, atomic weight 101.7, specific gravity 12.26; hard, brittle, steel gray, very infusible and almost insoluble in acids.

c) palladium; symbol Pd, atomic weight 106.7, specific gravity 11.8, silver-white, malleable and ductile.

Heavy-platinum group:

d) osmium; symbol Os; atomic weight 190.9, specific gravity 22.48, hard, blue-gray in colour, the heaviest known substance.

e) iridium; symbol Ir, atomic weight 193.10, specific gravity 22.4; white silver colour like platinum but harder, brittle and insoluble even in mixture of nitric and hydrocloric acids (aqua regia). It is also one of the heavier substances known to man.

f) platinum; see infra, n. 1.

4 a) Osmium has been used in the chemical industry where it is now less important than years ago;
b) In the dental-medical fields; however, the use of osmium has been on the increase; these are the two main areas of industrial consumption of osmium. For a very definitive work on the platinum group metals, see the comprehensive and detailed work by Thomas Patrick Mohide, Platinum Group Metals - Ontario and the World, Ministry of Natural Resources, Ontario Mineral Policy Background Paper No. 7, Toronto, March 1979. The contribution of this paper to the knowledge in the field of the PGMs is so substantial, particularly in the Ontario context, that anything attempted in the present report can only be complementary, except where new ground is covered with standing arguments expanded in greater detail.

5 PGMs used in the U.S. Automotive Industry (oz)

Year	Pt	Pd	Ir	Rh
1974	350,000	150,000	-	-
1975	273,000	97,000	-	-
1976	480,965	194,496	-	-
1977	354,338	127,316	-	-
1978	597,498	198,809	35	2,938

6 For the extrusion of fibreglass, platinum and rhodium-platinum bushings are used; they are called spinerets.

7 Ian Greig, "Platinum, a most noble metal," Optima, vol. 29, No. 1, September 30, 1980, p. 23.

8 W.C. Butterman, "Platinum-Group Metals," U.S.B.M., op. cit., p. 842.

9 Substitution could easily take place among metals of the same group. This may be true to some extent as iridium and ruthenium can substitute as hardeners. In the electrical field, substitutes are gold, silicon carbide, nickel, silver, molybdenum, tungsten chromium, cobalt, vanadium and silver; and possibly their alloys could function as catalysts. However, chemists warn against the necessity of such substitution possibilities of one catalyst metal for another. It depends on the specific functions and performance of catalysts serving a particular purpose.

10 Mohide, op. cit., p. 18.

11 Ibid., p. 66.

12 Ibid., pp. 62-63.

13 Butterman, loc. cit., p. 841.

14 Greig, loc. cit., p. 22.

15 Butterman, ibid.

16 Mohide, ibid., p. 63; for 1979, Greig places the quantity at 750,000 ounces or 23.3 metric tons, which is equivalent to 25 percent of all platinum consumed by the Western economies. Greig, ibid., p. 23.

17 For the conversion of sulphur dioxide into electricity to control environmental pollution a fuel-cell system was developed. For further information, consult: Dr. A Rubin, Dr. M. Leach and Dr. D. Goldsack, Dean of the Faculty of Science and Engineering, all at Laurentian University. They have solved, in the laboratory, this critical pollution problem emanating from ore smelters and conventional thermal power plants.

18 Greig, ibid., p. 25; esp. the United Technologies Corporation and Consolidated Edison are building this prototype plant for and under the auspices of the United States Department of Energy and the Electric Power Research Institute. Mohide has likewise paved the road into the future of fuel cells in a very optimistic light. See Mohide, ibid., pp. 69-70 for a very informative discussion.

19 Quantity Balance

Item	Exports (metric tons)			Item	Imports (metric tons)		
	1979	1978	1977		1979	1978	1977
256-29	4.91	10.56	12.39	455-12	0.692	0.748	0.684
256-39	1.531	1.324	0.994	455-22	0.231	0.253	0.317
455-29	1.736	0.911	1.119	455-25	0.5968	1.494	0.773
				455-29	2.295	3.158	2.476

Overall Balance Metric Tons

Year	Exports	Imports	Reexports	Balance
1979	8.177	2.295	n.a.	5.882
1978	12.795	3.158	0.169	9.468
1977	14.503	2.476	1.040	13.067

20 Butterman, ibid., p. 837.

21 Ibid.; also Mohide, op. cit., p. 54.

22 Mohide, ibid; he also provides a historical account of the events.

23 Mohide, ibid., and Butterman, ibid.

24 Ibid.

25 Mohide, ibid., p. 55.

26 Engelhard Minerals and Chemicals: Affiliates and Associates
ENGELHARD MINERALS & CHEMICALS CORP.
1221 Avenue of the Americas, New York/N.Y. 10020

Derby & Co. Ltd.	U.K.
Derby & Co. (Australia) Pty. Ltd.	Australia
Derby & Co. GmbH.	W. Germany
Derby & Co. (South Africa) (Pty.) Ltd.	South Africa
Derby Erz und Metall AG.	Switzerland
Derby Metals & Minerals Ltd.	Canada
RGB Pipelines Ltd.	U.K.
RGB Stainless Ltd.	U.K.
Charles Wade & Co.	U.K.
Derby Luminescents Ltd.	U.K.
Engelhard Industrien AG.	Switzerland
Engelhard Industrien GmbH.	Austria
Engelhard Industries A/S	Denmark
Engelhard Industries of Canada Ltd.	Canada
Engelhard Industries International Ltd.	Canada
Engelhard Industries International Corp.	Liechtenstein
The Sheffield Smelting Co. Ltd.	U.K.
Industrie Engelhard S.p.A.	Italy
Engelhard Industries (France) S.A. (A)	France
Engelhard Industries K.K.	Japan
Engelhard Industries Ltd.	U.K.
Engelhard Industries AB	Sweden
Engelhard Industries (South Africa)(Pty.) Ltd.	South Africa
Engelhard Sales Ltd.	U.K.
Engelhard Industries of Mexico S.A.	Mexico
Engelhard Industries S.A.	Belgium
Glover & Goode Pty. Ltd.	Australia
Engelhard Industries Pty. Ltd.	Australia
Engelhard Industries (Hong Kong) Ltd.	Hong Kong
Minero Mercantil del Peru S.A., Cia.	Peru
Phibro de Mexico S.A.	Mexico
Phibro S.A. Mineracao, Industria, Comercio, Exportacao e Importacao	Brazil
Usina Siderurgica Paraense S.A.	Brazil
Philipp Brothers (Belgium) S.A.	Belgium
Philipp Brothers (Canada) Ltd.	Canada
Philipp Brothers Far East Inc.	U.S.A.
Philipp Brothers (Overseas) Ltd.	Japan
Philipp Brothers (France) S.A.	France
Philipp Brothers GmbH.	W. Germany

Philipp Brothers (Holland) B.V.	Netherlands
Philipp Brothers Metal Corp.	U.S.A.
Philipp Brothers AG.	Switzerland
The Anglo Chemical & Orė Co. Ltd.	U.K.
Canadian Foreign Ore Development Corp. Ltd.	Bahamas
Denfort No. 3 Pty. Ltd.	Australia
Engelhard Minerals AG	Switzerland
Maden Eksport Ltd. Sirketi	Turkey
Metalmina Sales Corp.	Switzerland
Ore Chartering Ltd.	U.K.
Philipp Brothers AB	Sweden
Philipp Brothers Italia, S.p.A.	Italy
Philipp Brothers (Uruguay) S.A.	Uruguay
Suramco Trading Corp.	U.S.A.
Phibro AG	Switzerland
Victrix Corp.	Canada

Source: Who owns Whom, North America, 1979/1980, Dunn and Bradstreet, England, 1979.

27 Duncan R. Derry speaks of an aggregate length of 230 km vs 482 km (300 miles) in IMMR.

28 The following distribution among the contained PGMs has been observed: Pt: 62%; Pd: 24-26%; Ru: 6.5%; Rh: 3.5%; Ir: 1%; Os: n.a. Note also that Ni and Cu are of a relatively low grade.

29 Ian Greig, loc. cit., p. 29.

30 Operates under the names of two companies: TG Exploration in South Africa, and Pandora Mining, Pty. Ltd.

31 Operates under the name of Southern Sphere Mining and Development Corporation.

32 From the metallurgical point of view, certain innovations are recognizable. There is the "Expanded Precessive Plasma" system developed and patented by Tectronics Research and Development Co. Ltd., Faringdon, England. It works in the following way: fine metal concentrates are introduced into a high-temperature plasma cone for quick heating and smelting at a maximum temperature of 10,000°C. Texasgulf has expanded on this process and Tectronics and Foster Wheeler are enlarging the area of application of this process. Anglo-Transvaal has developed a cost-cutting and time-saving PGMs refining process. The National Institute for Metallurgy of South Africa has developed a new process to refine Rh, Ru and Ir; it is cost-cutting and recovery-efficient, uses a

solvent extraction method cum ion-exchange; it is also shortening significantly the refinery-run time. Lonrho is also known for using a new refining method for the same three metals.

33 The Platinum Mining Companies in South Africa are:
   a) Rustenburg Platinum Mines Ltd.
   b) Atok Mine, now controlled by Rustenburg
   c) Impala Platinum Holdings Ltd. (Union Corp. and INCO affiliates)
   d) Western Platinum (Lonrho and Falconbridge)
   e) Bantu Mining; a South African Government body in charge of the mineral concessions in the homeland of the native tribes. See Mohide, loc. cit., pp. 39-43.

34 IMMR, 1980, p. 188; see also by the same author viz. V.V. Strishkov M.A.R., 1980, loc. cit., p. 600.

35 IMMR, ibid.

36 In a discussion with a representative of the Geological Survey of Canada, who has visited the U.S.S.R., the opinion was expressed that the PGMs content of the nickel ores (Norilsk) are about one full ounce per metric ton of ore (32.1 g/t) which is almost three times as much as given by Mohide (11 g/t); Mohide, ibid., p. 25.

37 This point is to be credited to Dr. Paul Lindon, Director, School of Engineering, Laurentian University; formerly with Falconbridge Nickel Mines.

38 "U.S. strategic minerals stockpile to be revamped by new Administration," Engineering and Mining Journal, April 1981, p. 11.

39 Butterman, ibid., p. 839.

40 Ibid.

41 H.K. Conn, "The Johns-Manville Platinum-Palladium Prospect, Stillwater Complex, Montana, U.S.A.," Canadian Mineralogist, vol. 17, 1979, p. 467. Appreciation should be extended to Dr. R.S. James, Department of Geology, Laurentian University for this most inspiring reference as well as for other points raised in long discussions concerning especially the platinum metal geology and occurrences.

41a Engineering and Mining Journal, June 1981, p. 31, 201.

42 Butterman, ibid.

43 Mohide, op. cit., p. 83; he gives a ratio of Pd/Pt of 3.5:1; if this deposit could be exploited, it could free the U.S.A. from an import dependence on Russia, especially in respect to Pd.

44 James Ross and Reid R. Keays, "Precious Metals in Volcanic-type Nickel sulfide Deposits in Western Australia," Canadian Mineralogist, op. cit., p. 433.

45 Cells 1054 and 1108.

46 D.H. Watkinson and G. Dunning, "Geology and Platinum-Group Mineralization, Lac-Des-Iles Complex, Northern Ontario," Canadian Mineralogist, op. cit., pp. 453-462.

47 Ibid., p. 457. Concentrations of (11 g Pd and 1 g Pt)/mt have been reported/Boston Bay Mining and Texasgulf revealed an orebody of 35,000 metric tons per vertical meter grading 5.75 g PGE, 0.62 g Au, and 0.2% Cu-Ni.

48 It does not appear that the Onakawana Lignite deposits are of a quality to extract naphtha through hydrogenation.

49 Strategic Stockpile

	U.S. Objectives		U.S. Total Inventories	
	Ounces	Metric Tons	Ounces	Metric Tons
Ir	97,761	3.0	16,990	0.528
Pd	2,450,000	76.0	1,255,004	39.03
Pt	1,314,000	40.87	452,642	14.07

Source: A.B.M.S., Non-ferrous Metal Data, 1979, New York, N.Y., p. 146.

50 In 1978, if one follows Mohide's tabulation, the stockpiles were about 176.17 metric tons of all PGMs combined; see ibid., pp. 86, 121, 133, 142, 149 and 153.

51 Ibid., p. 86.

52 See Ian Greig, loc, cit., n. 7 infra, p. 31, who discusses the problems of platinum prices extensively, especially the new uncertainties caused on the demand side as manifested through the operations of the New York Mercantile Exchange operations.

53 Ian Greig, "Platinum Metals," M.A.R. 1980, p. 39.

54 Since the gold price forecast undertaken in this study is questionable after 1990, it is difficult to make a comparison of the two predicted prices as produced by the econometric model.

55 See Chapter I, pp. 57-58.

56 "Slower Growth Projected for Mining," Engineering and Mining Journal, January 1978, p. 63.

57 Mohide, op. cit., p. 74.

58 Butterman, loc. cit., p. 850, Table 9.

59 Mohide, ibid.

APPENDIX

Tables A1 - A7

Table A1

U.S. Consumption of Platinum Metals by Consuming Industry for the Years 1972, 1975, 1978

Total Platinum Group Metal used in troy ounces		Automotive Industry Share (%) Platinum Pt	Palladium Pd	Pt and Pd
1972	1,562,245	–	–	–
1973	1,833,901	–	–	–
1974	1,981,010	17.7	7.6	25.3
1975	1,310,037	20.8	7.4	28.2
1976	1,603,077	30.0	12.1	42.1
1977	1,592,277	22.3	8.0	30.3
1978	2,119,913	28.2	9.4	37.6

and 0.14 of one percent of rhodium

1972	Chemical	Petroleum	Glass	Electrical	Dental & Medical	Jewelry Arts	Misc	Total
Pt 2)	14.5	6.3	1.7	5.9	1.9	1.3	3.2	34.9
Ir	0.8	1.1	0.0	0.3	0.02	0.1	0.2	2.4
Pd	18.7	0.9	0.1	27.2	6.0	1.2	1.8	56.1
Os	0.01	–	–	–	0.02	–	0.0	0.05
Rh	1.0	0.0	0.9	0.5	0.00	0.4	0.1	2.9
Ru	2.6	–	–	0.4	0.00	0.1	0.3	3.4
Grand Total	37.7	8.3	2.7	34.3	8.1	3.2	5.6	– 99.9 *)

1975	Chemical	Petroleum	Glass	Electrical	Dental & Medical	Jewelry Arts	Misc	Total
Pt	11.4	8.2	2.6	5.6	1.3	1.7	1.8	53.3
Ir	0.2	0.3	0.0	0.2	0.0	0.0	0.0	0.7
Pd	10.9	0.2	1.3	10.1	8.8	1.8	0.9	41.4
Os	0.03	–	–	–	0.05	–	0.0	0.08
Rh	1.2	0.0	0.3	0.6	0.0	0.4	0.3	2.8
Ru	0.4	0.1	0.0	0.8	0.0	0.1	0.3	1.7
Grand Total	24.1	8.8	4.3	17.3	10.2	4.0	3.1	71.8 1)

...Cont'd.

Table A1 cont'd.

1978

	Chemical	Petroleum	Glass	Electrical	Dental & Medical	Jewelry Arts	Misc	Total
Pt	6.9	5.0	4.5	4.6	1.8	1.2	3.0	55.2
Ir	0.2	–	0.0	0.4	0.0	0.1	0.1	0.8
Pd	6.6	0.9	0.1	12.1	6.8	0.6	2.1	38.5
Os	5.5	–	–	–	0.04	–	–	0.04
Rh	0.9	0.0	0.8	0.4	0.0	0.3	0.3	2.8
Ru	0.8	–	0.0	1.6	0.0	0.0	0.2	2.6
Grand Total	15.4	5.9	5.4	19.1	8.8	2.2	5.6	62.4 1)

Source: American Metal Markets, Metal Statistics, 1979, New York, N.Y., p. 163. Research Computation

1) To the horizontal total have to be added, at least for the years 1975 and 1978, the respective shares of platinum and palladium absorbed by the automotive industry stated above.

2) Pt = platinum
Pd = palladium
Ir = iridium
Os = osmium
Rh = rhodium
Ru = ruthenium

*) Will not necessarily add to 100 percent due to rounding

Table A2

Exports of Platinum Metals (in scrap) for the Years 1977 to 1979

item 256-39

Year	troy ounces	metric tons	$Can '000
1979	49,221	1.531	15,115
1978	42,580	1.324	8,932
1977	31,973	0.994	3,297

Main Countries of Destination

1979	United States	91.9%
	West Germany	5.5%
	Japan	2.0%
	United Kingdom	0.6%
1978	United States	92.9%
	United Kingdom	7.1%
1977	United States	95.3%
	West Germany	4.4%
	United Kingdom	0.3%

Table A3

Exports and Imports of Platinum Metals Fabricated Materials n.e.s.

item 455-29

Year	Exports troy ounces	Exports metric tons	Exports '000 $Can.	Imports troy ounces	Imports metric tons	Imports '000 $Can
1979	55,808	1.736	7,189	22,267	0.692	6,256
1978	29,286	0.911	3,741	24,047	0.748	5,065
1977	35,984	1.119	4,400	21,994	0.684	3,837

Country of Destination Exports (quantities)

1979	United States	49.2%
	Japan	21.6%
	United Kingdom	21.5%
	Brazil	5.6%
	West Germany	2.1%
1978	United States	63.0%
	United Kingdom	29.9%
	France	3.5%
	Brazil	3.3%
	Switzerland	0.3%
1977	United States	91.4%
	West Germany	6.0%
	United Kingdom	2.5%
	Jamaica	0.08%
	Norway	0.02%

Country of Origin Imports (quantities)

1979	United Kingdom	62.0%
	United States	38.0%
1978	United Kingdom	69.5%
	United States	30.5%
1977	United Kingdom	57.2%
	United States	36.7%
	South Africa	5.5%
	Italy	0.5%
	Hongkong	0.1%

Table A4

Canadian Imports of Platinum Lumps, Ingots, Powder and Sponge

item 455-12

Year	troy ounces	metric tons	$Can.'000
1979	7,425	0.231	3,071
1978	8,126	0.253	2,600
1977	10,204	0.317	1,732

Countries of Origin

1979	United States	77.8%
	United Kingdom	22.2%
1978	United States	80.0%
	United Kingdom	20.0%
1977	United States	86.0%
	United Kingdom	14.0%

Table A5

Canadian Imports of Other Platinum Group Metals

for the Years 1977 to 1979

item 455-22

Year	troy ounces	metric tons	$Can.'000
1979	19,160	0.596	3,475
1978	48,043	1.494	2,043
1977	24,857	0.773	2,061

Countries of Origin

1979	United States	85.3%
	United Kingdom	14.2%
	Switzerland	0.5%
1978	United States	88.2%
	South Africa	6.8%
	United Kingdom	5.0%
1977	United States	87.6%
	South Africa	11.7%
	United Kingdom	0.7%

Table A6

Canadian Imports of Platinum Crucibles for the Years 1977-1979

item 455-25

Year	troy ounces	metric tons	$Can.'000
1979	24,941	0.776	15,001
1978	21,309	0.663	6,817
1977	22,563	0.702	5,627

Country of Origin

1977-1979 United States 100%

Table A7

Reexports of Platinum Metals refined and Semi-processed

Item 455 unspecified[1)]

Year	troy ounces	metric tons	$Can.'000
1978	5,441	0.169	334
1977	33,422	1.040	3,180

1) Source: Since Canadian exports by Commodity statistics do not specify the content of item 455, another source was used. J.J. Hogan, 'Platinum Metals' Bulletin, 1979. EMR. Ottawa. p. 342. Preliminary for Canadian Minerals Yearbook.